RESEARCH

THE ANTERIOR CRUCIATE LIGAMENT : EFFECT OF PASSIVE MOVEMENTS

Eddie Stoelwinder
Joe Farrell
Western Australian Institute of Technology

A mercury strain guage was used to analyze the affects of passive movement techniques upon the anterior cruciate ligament. One post-mortem subject was studied. Posterior-anterior pressures, with knee flexed to 90⁰ and medially rotated, revealed the most significant displacement of the anterior cruciate. It is suggested that combined movements may play a significant role in treatment of the knee joint

Manipulative therapists treat vertebral and peripheral joint disorders with a considerable amount of success. The assessment of symptomatic joints appears to be precise, and treatment is based upon accurate subjective and objective assessment. This is however, largely empirical and the effect of mobilization and manipulative techniques upon joint structures is questioned by the physician and manipulative therapist. Since many examination procedures are also utilized as treatment techniques, it seemed reasonable to study the effects of examination on the anterior cruciate ligament of the knee joint. Similar studies to this may lead to a better understanding of the effects of mobilization and manipulation upon other synovial joint structures.

There is considerable controversy concerning (a) the function, and (b) the clinical examination procedures for the anterior cruciate ligament. Most studies have involved the observation of changes in the stability of the knee joint after resection of the anterior cruciate. This method of observation is valuable in providing qualitative information, but not particularly useful in providing quantitative information.

Brantigan and Voshell (1941) reviewed contradictory statements describing the function of the cruciate ligaments. They found, that of 100 knee joints studied, both anterior and posterior ligaments are tense throughout flexion and hyperextension. In addition they found that if the anterior cruciate ligament was cut there was only a millimeter or two of forward gliding of the tibia in extension, but three times this movement possible in flexion.

Warren and Marshall 1978 reported that the anterior drawer sign, if present, increases the accuracy of diagnosis of anterior cruciate tear to 92%. However Hughston *et al.* (1976) found that rupture of the anterior cruciate ligament alone is not the primary cause of a positive anterior draw test. In reviewing 200 arthrotomies in which the anterior cruciate was described as "normal", he found that the ligament was not taut in 90 degrees of flexion. This led him to question the accuracy of the anterior drawer sign in diagnosing anterior cruciate tears.

Furman, Marshall and Girgis (1976) described the anterior cruciate as having two structural components, the posterolateral part and the anteromedial band. He found the anterior drawer sign is only elicited when the anteromedial band is severed.

Brantigan and Voshell (1941), Furman, Marshall and Girgis (1976), Kennedy, *et al.* (1974) conclude that the cruciate ligaments have an important role in (a) lateral and (b) rotatory motion (c) forward and (d) backward gliding of the tibia on the femur as well as (e) hyperextension and (f) hyperflexion. The exact role played by the ligament in movement, however, seems unclear.

Recently the use of a mercury strain guage has been described in measuring the deformation of the anterior cruciate ligament as a function of normal joint position (Kennedy, Hawkins and Willis, 1977). This method appears useful in that the anterior cruciate can be studied in a physiological manner with minimal joint destruction.

"The knee joint displays a certain amount of looseness, detectable on a clinical examination. Although an experienced clinician can detect relative differences in looseness, quantitive assessment is not easy". (Hsieh and Walker, 1977, p.10). It is evident that the amount of looseness is dependent upon (a) the amount of force applied,

Eddie Stoelwinder graduated with a Bachelor of Applied Science (Physiotherapy) from the Western Australian Institute of Technology in 1976. He completed the Graduate Diploma of Manipulative Therapy in 1979 and is currently in private practice.

Joe Farrell received a Certificate in Physical Therapy from Northwestern University in 1976. He completed the Graduate Diploma of Manipulative Therapy in 1979, and is currently enrolled in the Masters of Science (Health Sciences) programme at the Western Australian Institute of Technology.

and (b) elasticity of various restraining structures. According to Markoff, *et al.* (1978) the knee may be loose upon clinical examination yet stable during activity due to muscle power.

The aim of this study has been to (a) quantify the affects of passive movement procedures on the anterior portion of the anterior cruciate by mercury strain guage analysis, and (b) to present an experimental method which can be utilized by physiotherapists in order to study joint movement.

MATERIALS AND METHODS

To measure length changes of the anterior cruciate ligament a mercury strain guage was chosen because (a) it is small enough to fit into the knee joint (b) sensitive enough and pliable so as to not distort the action of the anterior cruciate, and (c) according to Kennedy, Hawkins and Willis (1977) the change in length of a ligament is accurately reflected in the mercury column. The strain guage consists of a 1mm diameter mercury filled silicon rubber tube sealed at its ends with copper wire (fig. 1). The guage used was based on a previous model (Kennedy, *et al.*, 1977) but was of a greater length in order to cover the whole of the anterior cruciate ligament. Previous studies (Kennedy *et al.* 1977; Danylchuk, 1975) have used a small 2.0 cm guage sutured only to the mid portion of the ligament.

The strain guage was calibrated by measuring electrical resistance as a function of distention of the mercury filled tube. This was checked for consistency with a model 270 plethymograph. Changes in the ligament length were transcribed onto a model 79 polygraph (fig. 2).

Previous strain guage analysis reports (Kennedy, *et al.*. 1977) used five fresh amputated specimens; while Danylchuk (1975) used both prepared cadaver and fresh specimens. Smith (1954) showed that death increased the elastic modules and tensile strength of the anterior cruciate ligament in rabbits. Walker *et al.* (1964) found an increase in the tensile strength of dried embalmed plantaris tendon when compared with moist specimens. Because of these findings a fresh non-amputated specimen was studied in an effort to closely simulate a clinical examination situation.

The specimen used was a 44 year old male whose death was attributed to cardiac failure six hours prior to our measurements. Visual observation showed that the subject did not have a deformity of either lower extremity, and that the articular joint surfaces did not show any signs of degeneration. Both anterior and the posterior cruciate ligaments appeared intact.

To gain access to the anterior cruciate ligament. two parapatellar incisions were carried out and the patellar tendon was transected at its attachment to

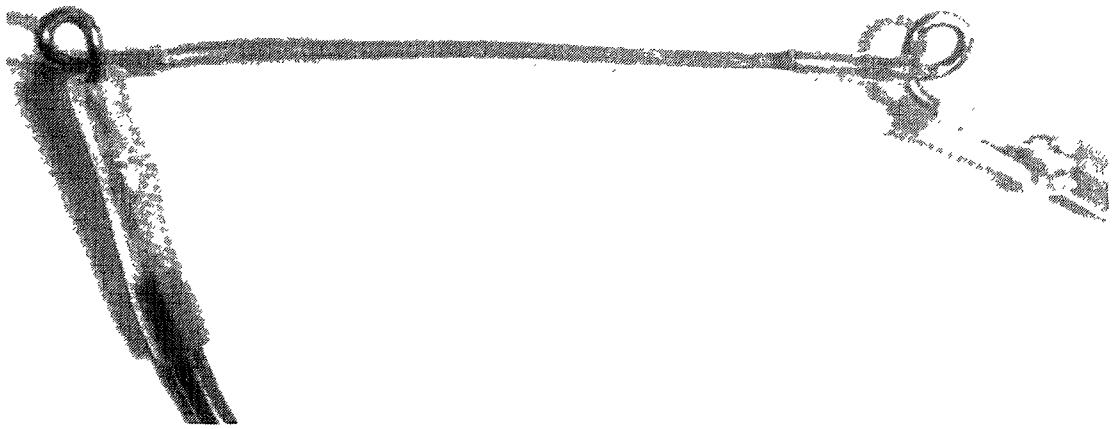

FIGURE 1: MERCURY STRAIN GUAGE. ARROWS INDICATE MERCURY COLUMN

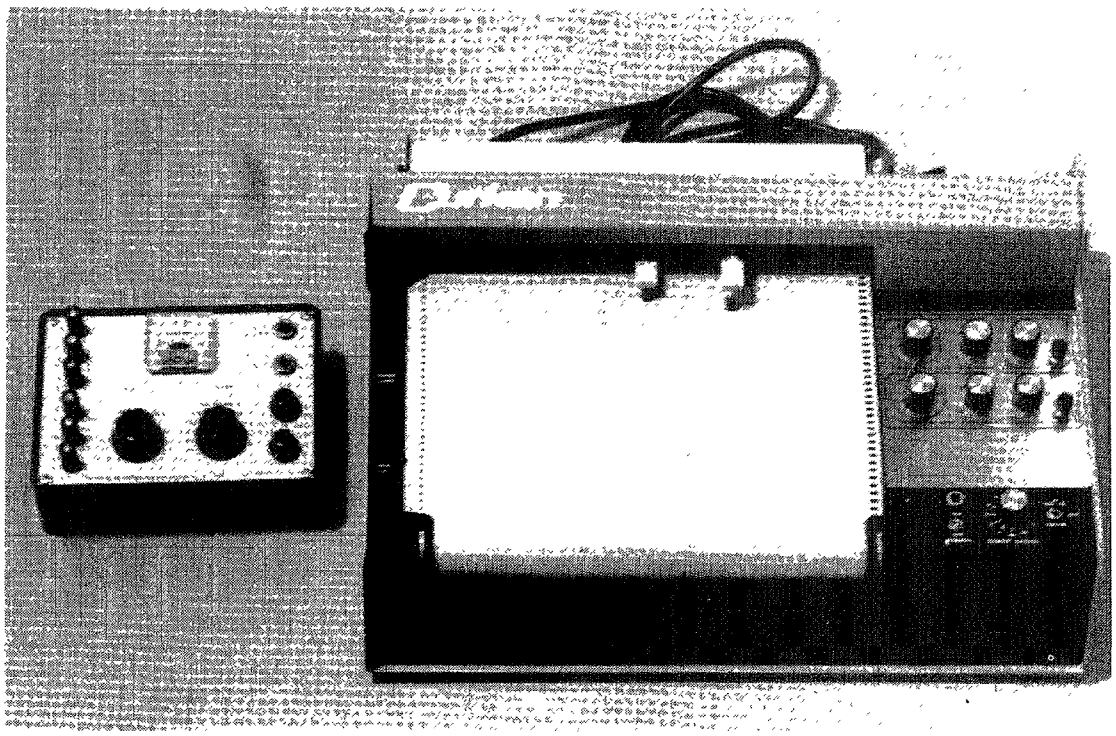

FIGURE 2:
LEFT: MODEL 270 PLETHYMOGRAPH RIGHT: MODEL 79 POLYGRAPH

the tibial tubercle. The patella and infra patellar structures were reflected proximally and the cruciates exposed. In order to locate the femoral attachment of the anterior cruciate a semicircular cavern of cancellous bone was removed deep into the lateral femoral condyle and intercondylar fossa. When most of the ligament was exposed the proximal pole of a 2.5 cm strain guage was sutured onto the ligament with the knee flexed to 90°. The distal aspect of the strain guage was sutured to the tibial attachment of the ligament under slight tension with the knee in 5° flexion.

Kennedy *et al.* (1977) and Danylchuk (1975) sutured the strain guage onto the mid-portion of the ligament with the knee in what they considered to be the most relaxed position (45° knee flexion). After viewing cadaver specimens, it was apparent that the anterior cruciate was most lax in knee extension. Furthermore, we decided to monitor length changes of the whole anterior ligament rather than just the mid-portion of the ligament as in the previous studies, and thus study the effect over the full length of this structure.

The prepared knee was examined in accordance with Maitland (1977) procedures. These procedures are listed on Table 1 with results.

RESULTS

The results of the study are indicated in Table 1. These findings conflict on some issues with the results from previous studies (Kennedy *et al.*, 1977, Danylchuk, 1975). Because our strain guage requires further refinement the results are presented in a qualitative manner.

Generally as the knee was flexed tension of the anterior cruciate increased and extension movements loosened the ligament. Medial glides produced a tightening affect at 30° and 60°, and loosening at 90° flexion. Lateral glides produced the reverse of the medial glides. Antero-posterior and postero-anterior movements produced tightening at 90° flexion, whilst at 60° flexion antero-posterior movements tightened and postero-anterior movements loosened. Abduction tightened at 0° and 30° flexion while adduction loosened the anterior cruciate. Lateral rotation of the tibia on the femur revealed tightening in all positions, whereas medial rotation produced tightening at 30° flexion, and loosening at 60° and 90° flexion. The antero-posterior and postero-anterior 90° flexion movements combined with medial and lateral rotation of the tibia on the femur had a tightening affect. The maximum tightening showed upon postero-anterior movement with the tibia medially rotated.

TABLE 1

PASSIVE MOVEMENT ANALYSIS

TEST		0° EXTENSION	30° FLEXION	60° FLEXION	90° FLEXION
Extension over pressure		L (T, T.)	-	-	-
Extension Abduction (E/Ab)		L	-	-	-
Extension Abduction (E/Ad)		L	-	-	-
Medial Glide of Tibia (M →)		L	T	T	L
Lateral Glide of Tibia (L ←)		L	L	L	T
Antero-Posterior or Posterior Drawer	(↑)	0	-	T	T (L,L.)
Postero-Anterior or Anterior Drawer	(↓)	T	-	L	T (T,L.)
Abduction (Ab)		T	T (L,-.)	-	-
Abduction (Ad)		L	L (T,-.)	-	-
Medial rotation of tibia (M)		-	T (T,T.)	L (-,T.)	
Lateral rotation of tibia (L)		-	T (L,L.)	T (-,L.)	T (-,L.)
↑ With tibia in (M)	*	-	-	-	T
↑ With tibia in (L)	*	-	-	-	T
↓ With tibia in (M)	*	-	-	-	T
↓ With tibia in (L)	*	-	-	-	T

* Combined movements as described by Hughston (1976)

Legend :
T = Tightening
L = Loosening
O = No change
\- = Not tested

(Results in parenthes are the results of Kennedy *et al.* (1977) and Danylchuck (1975) in that order)

DISCUSSION

The results of this study agreed with Kennedy, *et al.* (1977), and Danylchuk (1975) in two ways:

1) tightening affects upon postero-anterior movement with knee flexed 90° and tibia in neutral rotation,
2) the anterior cruciate tightened with increased knee flexion.

In full extension the displacements recorded were small. This may be because the strain guage was sutured onto the anterior cruciate ligament with the knee in extension rather than 45° flexion as performed by Kennedy, Hawkins and Willis (1977). Antero-posterior and postero-anterior movements were performed in 90° knee flexion combined with medial and lateral rotation of the tibia as suggested by Hughston *et al.* (1976). The above movements all showed a tightening affect upon the anterior cruciate. The largest displacement occurred with a postero-anterior movement with the tibia medially rotated. This finding may be expected since Kennedy, *et al.* (1977) found that separately medial rotation, flexion, and postero-anterior movements tighten the anterior cruciate ligament.

We are unable to explain the reason why the anterior cruciate ligament tightens during anterior and posterior drawing combined with medial and lateral rotation. However, this result may be

related to the orientation of musculature and ligamentous attachment, bony contours of the articular surface, as well as fibre orientation of the anterior cruciate ligament. Furthermore, only one cadaver specimen has been studied to date.

In this study, lateral rotation in all degrees of flexion tightened the anterior cruciate, whereas medial rotation generally relaxed the ligament, except in 30° of knee flexion when it tightened the ligament. This is opposite to the findings of Kennedy, Hawkins and Willis (1977) and Danylchuk (1975). In abduction (valgus) the ligament tightened and loosened with adduction (varus). This again is opposite to the findings of the previously cited authors.

These differences may be attributed to the following:

(a) the whole body sample was used without mechanical stabilization of the femur in this study
(b) rigor mortis affects both hip and knee mobility
(c) the position and length of the mercury strain guage is different
(d) there was some interference of read-outs from the wires connecting the mercury column
(e) limited sample (1 subject)
(f) the patellar tendon was not resutured to the tibial tubercle prior to the movement study.

CONCLUSION

This has been a pilot study, and therefore the results cannot be considered conclusive, but they indicate that further research of this nature ought to be continued. Similar methods can be used by physiotherapists to quantify the effects of passive movement on structures.

With the knee flexed to 90°, the combination of medial rotation of the tibia and postero-anterior movements produced the greatest tightening affect on the anterior cruciate ligament, although each of these movements on their own produces only small displacements. This may indicate the value of combined movements which are utilized in assessments and treatment. These findings may be more meaningful when related to neurophysiology, pathology, and the total clinical presentation.

ACKNOWLEDGEMENT

Our thanks for the encouragement and constructive criticism of this pilot study must be directed to Dr Andy Wilson, Associate Dean of Medicine, University of Western Australia, and Mr Lance Twomey, Head of Department of Physiotherapy, Western Australia Institute of Technology.

BIBLIOGRAPHY

Brantigan, O.C. and Voshell, A.F. 1941. "The Mechanics of the Ligaments and Menisci of the Knee Joint", *Journal of Bone and Joint Surgery*, 23A(1): 44-66.

Danylchuk, K.D. 1975. "Studies of the Morphometric and Biomechanical Characteristics of Ligaments of the Knee Joint". *Partial Fulfillment of Requirement of the Degree of Master of Science*, University of Western Ontario, London, Canada.

Furman, W., Marshall, J.L. and Girgis, F.G. 1976. "The Anterior Cruciate Ligament", *Journal of Bone and Joint Surgery*, 58A(2): 179-185.

Hsieh, H. and Walker, P. 1977. "The effect of Compressive Load on the Stability of the Knee Joint", *Bulletin of the Hospital for Joint Disease*, 38(1): 10-14.

Hughston, J.C., Andrews, J.R., Cross, M.J. and Moschi, A. 1976. "Classification of Knee Ligament Instabilities, Part 1. The medical Compartment and Cruciate Ligaments", *Journal of Bone and Joint Surgery*, 58A(2): 159-172.

Kennedy, J.C., Hawkins, R.J. and Willis, R.B. 1977. "Strain Guage Analysis of Knee Ligaments", *Clinical Orthopaedics and Related Research*, 129: 225-229.

Kennedy, J.C., Weinberg, H.W. and Wilson, A.S. 1974. "The Anatomy and Function of the Anterior Cruciate Ligament", *Journal of Bone and Joint Surgery*, 56A(2): 223-235.

Khasigian, H.A., Evanski, P.M. and Waugh, T.R. 1978. "Body Type and Rotational Laxity of the Knee", *Orthopaedics and Related Research*, 130: 228-232.

Maitland, G.D. 1977. *Peripheral Manipulation*. 2nd ed. Butterworths, London.

Markolf, K.L., Graff-Radford, A. and Amstutz, H.C. 1978. "In Vivo Knee Stability", *Journal Bone and Joint Surgery*, 60A(5): 664-674.

Smith, J.W. 1954. "The Elastic Properties of the Anterior Cruciate Ligament of the Rabbit", *Journal of Anatomy*, 88: 369-380.

Walker, L.B., Harris, E.H. and Benedict, J.V. 1964. "Stress-Strain Relationship in Human Cadaveric Plantaris Tendon: A Preliminary Study", *Medical Electronics and Biological Engineering*, 2: 31-38.

Warren, R.F. and Marshall, J.L. 1978. "Injuries of the Anterior Cruciate and Medial Collateral Ligaments of the Knee", *Clinical Orthopaedics and Related Research*, 136: 191-197.